How many people would survive if all emergency medical systems in the United States approached the hypothesized maximum survival rate of 20% that occurs in these mature EMS systems? If an estimated 3% survival rate[148] is applied to the presumed annual 400,000 cardiac arrests, approximately 12,000 people per year now survive out-of-hospital cardiac arrest.[147] A 20% survival rate for this population of nontraumatic cardiac arrest patients would yield 80,000 survivors, or an additional 68,000 people. The American Heart Association estimates that nationwide implementation of all life-saving emergency cardiac care mechanisms in each community may save between 100,000 and 200,000 lives annually in the United States.[1] Without proper implementation of a full prehospital care system, however, emergency services cannot achieve such rates. People not resuscitated before hospital arrival rarely survive.[150,151]

Figure 2.*Ventricular fibrillation survival rates over time. Percentage of people in nontraumatic cardiac arrest with initial rhythm ventricular fibrillation who survive to hospital discharge. Data from King County, Washington, Division of Emergency Medical Services, Seattle-King County Department of Public Health, Seattle.*

Design Imitation?

Is it possible for EMS systems to imitate the design of more successful locations and thus achieve the same survival rates? Table 3 summarizes data published on cardiac arrest survival from many cities worldwide.[31, 33-35, 38, 39, 43, 76-90, 101, 119, 120, 142, 143, 152-158.] These data show marked variation in survival rates among the different types of EMS systems, ranging from 5% to 17% survival for patients in all cardiac arrest rhythms and from 12% to 29% for patients specifically in ventricular fibrillation.

Simple structural imitation of successful EMS organizations, however, does not always succeed. Even in locations with similarly structured EMS systems, marked differences in the observed survival rates persist. For example, studies from 15 different paramedic-only or doctor-manned ambulance systems (Table 3, row C) reported survival rates from 7% to 18% for all rhythms and from 13% to 30% for ventricular fibrillation.[6,33-35,76-86] Table 3 summarizes results from nine EMT-paramedic systems (row D). These systems display the same wide variations.[33,38,39,101,154-158]

It is unclear exactly why these differences occur within the same types of systems. Part of the explanation is that definition of terms and reporting of data are not standardized.[159] While some researchers have proposed uniform reporting systems, many others have pointed to the need for an international standardized nomenclature.[18,27,35,39,87,159,160] Regardless, part of these differences may very well be due to variable effectiveness or lack of EMS medical leadership and direction.[161-165]

It can also be argued that similarly constructed systems have different survival rates because they differ in how well they develop and implement each link in the chain of survival.[87,163,166] This appears particularly true for early initiation of CPR and early arrival of personnel trained to operate a defibrillator. Many cities in the United States, for example, established a strong link for early advanced life support by starting paramedic services at great expense and effort.[33-35,76-86] Most of these paramedic-only systems have achieved disappointingly low survival rates. In part this is because citizens in these locations seldom attempted to perform CPR. In addition, long paramedic response times, in the absence of an early defibrillation program, precluded early defibrillation and early advanced care. In paramedic-only systems, paramedics are generally preoccupied with many other minor emergencies and consequently are less available (and less skilled) to deal with cardiac arrest patients.[163]

To strengthen the early CPR link in the chain of survival, several EMS systems have mounted extensive CPR campaigns. They have trained a large percentage of the

population in basic CPR skills. Unfortunately, these systems also have observed diminished survival rates because they failed to provide an emergency medical service with rapid defibrillation and rapid advanced life support.[18,39,43,78,153,155] Enhancements of early CPR programs, such as targeted CPR training[10,53-59] and dispatcher-assisted CPR programs,[51,65,67] will also fail if defibrillation does not occur soon after collapse.

Conversely, systems that have established early defibrillation programs by training their less advanced ambulance personnel to use defibrillators[43,90,119,120,142] may experience low success rates if they do not also train citizens to recognize cardiac arrest early or to call the emergency service immediately. The defibrillator will not arrive quickly enough if the EMS system is not called immediately, if local ambulances or first-responder units are not equipped with defibrillators, or if managers do not strategically deploy emergency response vehicles with defibrillators.

Responsible people must apply continuous quality improvement concepts to each link in the chain of survival. In early CPR, for example, it is not only a matter of the number of people who are trained. Systems can achieve better results by targeting the right groups and evaluating training programs, short-term results, and long-term trends. Automated defibrillators must be placed, then complemented with carefully planned training and follow-up programs and close medical control of the system, including individual case reviews and overall data management programs. Without these quality improvement methods, a system will not realize the full benefit of any new organization.

Summary

The chain of survival concept embodies standard principles of system management. The phrase restates[167] the familiar emergency medical services continuum pioneered by Peter Safar, who coined the term *life support chain.*[168] Other authors have referred to the concept with various phrases.[1,3,20,23,140] As a pedagogic construct, it emphasizes that there are no easy, single-step approaches to improving survival from cardiac arrest.[166,167]

Early access to the EMS system ensures early CPR, defibrillation, and advanced care. Early access is easiest to achieve with 911 systems and widespread community education and publicity. Instructors may also teach early access during citizen CPR classes. Early CPR helps patients by slowing the process of dying, but its effectiveness disappears within minutes, and defibrillation must soon follow. Early recognition and early CPR are best achieved when citizens are well informed about cardiac emergencies and well trained in CPR. The earliest possible delivery of defibrillation is critical and almost by itself is sufficient for many victims of sudden cardiac death.
Defibrillation has therefore emerged as the single most effective intervention for patients in nontraumatic cardiac arrest. Automated external defibrillators help to accomplish this goal and permit widespread implementation of a variety of early defibrillation programs. Early advanced care helps those who do not immediately convert to an organized cardiac activity or who do not achieve a spontaneous circulation following early defibrillation. Advanced care allows the highest possible survival rate through respiratory and antiarrhythmic stabilization and monitoring of patients in the post-resuscitation period.

At present, early CPR and rapid defibrillation, combined with early advanced care, can result in long-term survival rates for witnessed ventricular fibrillation as high as 30%. Researchers have observed that neurological and psychological recovery from cardiac arrest depends on the time within which these critical interdependent treatment modalities are delivered.[22,169] Therefore, high resuscitation rates will also lead to a high percentage of patients who recover to the neurological level they had before their arrest.

The future of the chain of survival will be highly dependent on multicenter cooperative studies of cardiac arrest in both in-hospital and out-of-hospital settings.[150,162,170] In addition to scientific research, the training of those responsible for implementing and maintaining the chain of survival must become a priority.[150,162,164] For emergency medical services the challenge is to develop programs that will allow recognition, access, bystander CPR, defibrillation, and advanced care to occur as quickly as possible. Ideally systems should deliver these interventions within moments after sudden death victims collapse. Achievement of such a goal requires the deployment of multiple, properly directed programs, within an EMS system. Each program should lend strength to the chain of survival, thereby enhancing successful recovery and long-term survival.

Recommendations

The Advanced Cardiac Life Support Subcommittee and the Emergency Cardiac Care Committee of the American Heart Association recommend that all communities take the following actions to strengthen their Chain of Survival:

1. Early Access

- All communities should implement an enhanced 911 system.
- All communities should develop education and publicity programs that focus on cardiac emergencies and a proper response by citizens.

2. Early CPR

- Communities should continue to vigorously implement and support community-wide CPR training programs.
- Community CPR programs should emphasize early recognition, early telephone contact with the EMS system, and early defibrillation.
- Community CPR programs should develop and use training methods that will increase the likelihood that citizens will actually initiate CPR.
- Communities should adopt more widespread and effective targeted CPR programs.
- Communities should implement programs to establish dispatcher-assisted CPR.

3. Early Defibrillation

- All communities should adopt the principle of early defibrillation. This principle applies to all personnel who are expected, as part of their professional duties, to perform basic CPR: they must carry an automated external defibrillator and be trained to operate it.
- Health professionals who have a duty to respond to a person in cardiac arrest should have a defibrillator available either immediately or within 1-2 minutes.
- Responsible personnel should authorize and implement more widespread use of automated external defibrillation by community responders and allied health responders.

4. Early Advanced Life Support

- Advanced life support units should be combined with first-responding units that provide early defibrillation.
- Advanced life support units should develop well-coordinated protocols that combine rapid defibrillation by first-responding units with rapid intubation and

intravenous medications by the advanced cardiac life support units.

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